भारतीय मानक **IS 7494 : 2023**

Indian Standard

आंतरिक दहन इंजन वाल्व अनुप्रयोगों के लिए मिश्र धातु — विशिष्टि

(दूसरा पुनरीक्षण)

Alloys for Internal Combustion Engine Valve Applications — Specification

(Second Revision)

ICS 27.020; 77.140.10; 77.140.20

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Alloy Steels and Forging Sectional Committee, MTD 16

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Alloy Steels and Forging Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1974 and subsequently revised in 1981. Based on experience gained in the production and use of these alloys, the following major modifications have been incorporated in the current revision:

a) The grades V-1, V-2, V-3, V-4, V-5, V-6, V-7, V-9, V-11, V-13 were excluded;
b) The grades V-8, V-10, V-12, V-14 and V-15 were re-designated. In addition, requirements for these grades were aligned with those prevailing across the automobile industry;
c) Fifteen new grades of majorly used valve alloys and comprising of stainless steels, super alloys and titanium alloys were included;
d) A comparative list indicating grades of valve alloys covered in various designation systems is added and given at Annex A for purpose of information only;
e) Mechanical properties at room temperature for material supplied in heat-treated condition is added;
f) Requirement of inclusion rating is modified to suit the purpose; and
g) Reference data on physical properties of valve alloys is added.

While revising this standard, due consideration has been given to Part 15 ‘Valve steels for internal combustion engines’ of ISO 683-15 : 1992 ‘Heat-treatable steels, alloy steels and free-cutting steels’.

The composition of the Committee responsible for the formulation of this standard is given in Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ALLOYS FOR INTERNAL COMBUSTION ENGINE VALVE APPLICATIONS — SPECIFICATION

(Second Revision)

1 SCOPE

This standard covers the technical and delivery requirements for alloys supplied in the form of round bars and wire rods, up to 40 mm size, used for manufacturing of inlet and exhaust valves of reciprocating internal combustion engines.

2 REFERENCES

The standards listed in Annex A contain provisions, which, through reference in this standard, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards.

3 TERMS AND DEFINITIONS

For the purpose of this standards, the definitions given in relevant parts of IS 1956 and the following shall apply:

3.1 Valve Alloys — Alloys for reciprocating internal combustion engine valves mentioned in the standard comprising of martensitic steels, austenitic steels, super alloys and titanium alloys.

4 SUPPLY CONDITIONS

4.1 General requirements related to the supply of material shall conform to IS 8910.

4.2 The bars may be supplied without heat treatment or with heat treatment conditions such as annealed/solution treated/quenched and tempered.

4.3 Unless otherwise specified, materials shall be supplied in the form of a bar/wire rod with one of the following surface finishes:

a) Peeled and polished;
b) Ground;
c) Peeled and ground, then polished;
d) Peeled and ground;
e) Ground and polished; and
f) As-rolled.

5 CLASSIFICATION

5.1 The valve alloys listed are classified according to their chemical composition into four categories as under:

a) Martensitic steels (VM);
b) Austenitic steels (VA);
c) Super alloys (VSA); and
d) Titanium alloys (VTA).

5.2 Annex B provide a comparable list of various designation systems in other national/international/ association standards.

6 MANUFACTURE

Unless otherwise agreed in the order, the types of melting, re-melting, and thermo-mechanical processes shall be at the discretion of the manufacturer.

7 CHEMICAL COMPOSITION

7.1 Ladle Analysis

The ladle analysis of the alloys, when carried out by any established instrumental/chemical method, shall conform to the requirements as given in. In case of dispute, the procedure given in IS 228 and its relevant parts shall be the referee method. Wherever test methods are not specified, the same shall be as agreed to between the purchaser and the manufacturer/supplier.

7.2 Product Analysis

The product analysis shall be carried out on the finished product from the standard position given in IS/ISO 14284. Permissible limits of variation in case of product analysis from the limits specified in Table 1 shall be as given in Table 2.

8 FREEDOM FROM DEFECTS

8.1 Material shall be free from harmful internal and surface defects.

8.2 Unless otherwise specified in the order, the depth of surface defect for peeled or ground bars shall not exceed the tolerance class h11 given in IS 919 (Part 2).

9 MECHANICAL PROPERTIES

9.1 For the material supplied in heat-treated condition mechanical properties at room temperature shall be as given in Table 3. Tests for hardness shall be carried out in accordance with IS 1500 (Part 1) and the test for tensile properties shall be carried out in accordance with IS 1608 (Part 1).

9.2 For alloys supplied in as-rolled condition, mechanical properties shall be mutually agreed to between the manufacturer and the purchaser.

9.3 Unless otherwise specified in the order, Mechanical properties referred in Table 5, Table 6 and Table 7 are for guidance only. Reference values for mechanical properties at room temperature are given in Table 5, reference values for tensile properties at elevated temperature are given in Table 6 and reference values for creep strength after 1 000 h are given in Table 7.

9.3.1 The properties given in Tables 5, Table 6 and Table 7 can be verified on specimens which are taken from the product, as given in IS 3711, and are to be heat-treated according to the particulars given in Table 4.

9.3.2 Hardness test shall be carried out in accordance with IS 1500 (Part 1) or IS 1586 (Part 1).

9.3.3 Tensile test shall be carried out as per IS 1608 (Part 1) and IS 1608 (Part 2) for room and elevated temperatures respectively.

9.3.4 Creep testing shall be carried out in accordnace with IS 3407 (Part 1)/IS 3407 (Part 2)/IS 17795 as applicable.

10 GRAIN SIZE

Grain size of the delivered material shall be measured in accordance with IS 4748. Unless otherwise specified in the order, grain size in delivery condition shall be finer or equal to class 6.

11 NON-METALLIC INCLUSIONS

11.1 Inclusion rating of the steel shall be determined in accordance with IS 4163. The worst field of each inclusion from each specimen shall be recorded as a rating for the specimen. Inclusion index of the specimen shall not exceed the following limits for air-melted steels such as martensitic and austenitic steels:

Sl No.	*Group*	*Inclusion Type*	*Inclusion Index*	
			Fine Series, Max	*Thick Series, Max*
(1)	(2)	(3)	(4)	(5)
i)	A	Sulphide	2.5	1.5
ii)	B	Alumina	2.5	1.5
iii)	C	Silicate	2.5	1.5
iv)	D	Globular oxide	2.5	1.5

NOTE — For vacuum melted/re-melted alloys such as super alloys and titanium alloys, inclusion level shall be mutually agreed upon at time of ordering.

12 PHYSICAL PROPERTIES

For the purpose of guidance, physical properties of the alloys are given in Table 8.

13 DIMENSIONS AND TOLERANCES

a) The dimensions and tolerances of the product shall comply with the requirements agreed upon at the time of inquiry and order;

b) The dimensional tolerance for steel bars shall be in accordance with IS 3739;

c) For forged bars, the tolerances shall be as specified in IS 10604 (Part 2);

d) Tolerances of drawn and centre less ground bars shall be as per IS 919 (Part 1) and (Part 2); and

e) Tolerances of wire rods shall be as per IS/ISO 16124.

14 SAMPLING

14.1 Product Analysis

The ladle analysis shall be supplied by the producer. If a product analysis is required by the purchaser, at least one sample product shall be taken from each cast from the standard position given in IS/ISO 14248.

14.2 Hardness Test

One sample product shall be taken from each heat-treated batch subject to the minimum of at least one sample from each cast for the determination of hardness. Location of sample should be as mentioned in IS 3711.

If the product is continuously heat-treated, the sampling for hardness tests shall be as agreed to between the purchaser and the manufacturer.

14.3 Tensile Test

If required by the purchaser, one sample product shall be taken from each size grouping of each heat-treated batch for testing. Test piece for the tensile test shall be taken in the longitudinal direction of the product (in accordance with Fig. 1). Location of sample should be as mentioned in IS 3711.

If the product is continuously heat-treated, the sampling for tensile tests shall be as agreed to between the purchaser and the manufacturer.

15 RETEST

15.1 Product Analysis

If the result of the product analysis does not meet the composition requirements given in Table 1 and Table 2. Unless otherwise agreed to between the purchaser and manufacturer, two new samples shall be taken on different pieces from the same cast. If two samples analysis satisfies the requirements, then the whole lot shall be accepted. If any of the two samples fail, the lot shall be rejected.

15.2 Mechanical properties

If the sample selected under sections **14.2** and **14.3** fail to meet the requirements, further two samples shall be taken from the same heat-treated batch or lot. If two samples analysis satisfies the requirements then the whole lot shall be accepted. In case the samples fail, the manufacturer shall have the right to achieve desired properties employing re-heat treatment. After that, two fresh samples shall be tested accordingly. If sample analysis satisfies the requirements then the whole lot shall be accepted. If any of the two samples fail, the lot shall be rejected.

16 PACKING AND MARKING

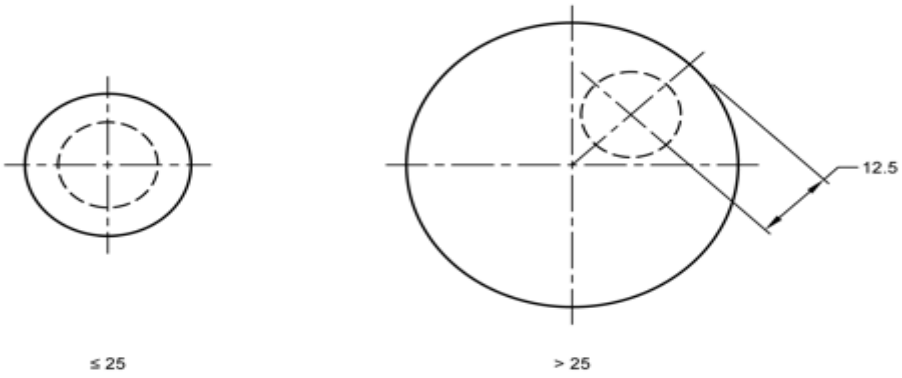
16.1 Bars shall be suitably bundled. Each coil of wire rod shall be bound and fastened compactly.

16.2 A metal tag attached to each bundle and label affixed on the coil shall give the following information:

a) Name and trademark of the manufacturer;
b) Material grade and size;
c) The cast number or any other identification mark by which the material can be traced to the cast and heat treatment batch;
d) Heat treatment condition; and
e) Surface finish.

16.3 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed there under, and the products may be marked with the Standard Mark.



All dimensions in millimetres.

NOTE — Sampling for hardness and mechanical properties in a condition other than heat-treated condition shall be as agreed to by the purchaser and the manufacturer.

FIG.1 LOCATION OF TENSILE TEST PIECES

Table 1 Chemical Composition, Percent

(*Clause* 7.1)

Sl No.	Designation		C	Si	Mn	P	S	Cr	Mo	Ni	V	Nb	Ti	Others
	Number	Grade												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Martensitic Steels														
i)	VM-1	X45CrSi 9-3	0.40 to 0.50	2.70 to 3.30	≤ 0.80	≤ 0.040	≤ 0.030	8.00 to 10.00	—	≤ 0.60	—	—	—	—
ii)	VM-2	X40CrSiMo 10-2	0.35 to 0.45	2.00 to 3.00	≤ 0.80	≤ 0.040	≤ 0.030	9.50 to 11.50	0.80 to 1.30	≤ 0.50	—	—	—	—
iii)	VM-3	X50CrSi8-2	0.45 to 0.55	1.00 to 2.00	≤ 0.60	≤ 0.030	≤ 0.030	7.50 to 9.50	—	≤ 0.60	—	—	—	—
iv)	VM-4	40CrMoV47	0.36 to 0.44	0.15 to 0.35	0.45 0.70	≤ 0.040	≤ 0.040	0.80 to 1.15	0.50 to 0.65	—	0.25 to 0.35	—	—	—
v)	VM-5	X85CrMoV 18-2	0.80 to 0.90	≤ 1.00	≤ 1.50	≤ 0.040	≤ 0.030	16.50 to 18.50	2.00 to 2.50	—	0.30 to 0.60	—	—	—
Austenitic Steels														
vi)	VA-1	X55CrMnNiN 20-8	0.50 to 0.60	≤ 0.25	7.00 to 10.00	≤ 0.050	≤ 0.030	19.50 to 21.50	—	1.50 2.75 to	—	—	—	N = 0.20 to 0.40
vii)	VA-2	X53CrMnNiN 21-9	0.48 to 0.58	≤ 0.25	8.00 to 10.00	≤ 0.050	≤ 0.030	20.00 to 22.00	—	3.25 to 4.50	—	—	—	N = 0.35 to 0.50
viii)	VA-3	X33CrNiMnN 23-8	0.28 to 0.38	0.50 to 1.00	1.50 to 3.50	≤ 0.050	≤ 0.030	22.00 to 24.00	≤ 0.50	7.00 to 9.00	—	—	—	W = ≤ 0.50, N = 0.25 to 0.35
ix)	VA-4	X20CrNiMnN 21-12	0.15 to 0.25	0.70 to 1.25	1.00 to 1.50	≤ 0.045	≤ 0.030	20.00 to 22.00	—	10.50 to 12.50	—	—	—	N = 0.15 to 0.25
x)	VA-5	X50CrMnNiNbN 21-9	0.45 to 0.55	≤ 0.45	8.00 to 10.00	≤ 0.050	≤ 0.030	20.00 to 22.00	—	3.50 to 5.50	—	—	—	W = 0.80 to 1.50, Nb + Ta = 1.80 to 2.50 N = 0.40 to 0.60

Table 1 (*Continued*)

Sl No.	Designation		C	Si	Mn	P	S	Cr	Mo	Ni	V	Nb	Ti	Others
	Number	Grade												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Super Alloys														
xi)	VSA-1	NiCr20TiAl	0.04 to 0.10	≤ 1.00	≤ 1.00	≤ 0.020	≤ 0.015	18.00 to 21.00	—	≥ 65.00	—	—	1.80 to 2.70	Al = 1.00 to 1.80, B = ≤ 0.008 Co = ≤ 2.00, Cu = ≤ 0.20 Fe = ≤ 3.00
xii)	VSA-2	NiCr15Fe7TiAl	0.03 to 0.10	≤ 0.50	≤ 0.50	≤ 0.015	≤ 0.015	14.00 to 17.00	≤ 0.50	Base	—	—	2.00 to 2.60	Al = 1.10 to 1.35, Nb+Ta = 0.70 to 1.20, Fe = 5.00 to 9.00,
xiii)	VSA-3	NiCr22TiMoAl	0.03 to 0.06	≤ 0.20	≤ 0.20	≤ 0.015	≤ 0.015	22.30 to 22.90	1.70 to 2.30	55.00 to 58.00	—	—	—	Ti = 2.10 to 2.60, Al = 1.00 to1.70 Nb = 0.60 to 1.20, B = 0.008 *Max*
xiv)	VSA-3	NiCr22TiMoAl	0.03 to 0.06	≤ 0.20	≤ 0.20	≤ 0.015	≤ 0.015	22.30 to 22.90	1.70 to 2.30	55.00 to 58.00	—	—	—	Ti = 2.10 to 2.60, Al = 1.00 to1.70 Nb = 0.60 to 1.20, B = 0.008 *Max*
xv)	VSA-4	NiCr22TiMoAlCo	≤ 0.20	≤ 0.20	≤ 0.20	≤ 0.015	≤ 0.015	22.30 to 22.90	1.70 to 2.30	55.00 to 58.00	—	—	—	Ti = 2.10 to 2.40, Al = 1.10 to1.40 Nb = 0.70 to 1.00, Cu = ≤ 0.50 B = ≤ 0.008, Co = ≤ 1.00
xvi)	VSA-5	NiFe25Cr20NbTi	≤ 0.10	≤ 1.00	≤ 1.00	≤ 0.030	≤ 0.015	18.00 to 21.00	—	Base	—	—	—	Al = 0.30 to 1.00 Nb + Ta = 1.00 to 2.00 B = ≤ 0.008, Ti = 1.00 to 2.00 Fe = 23.00 to 28.00
xvii)	VSA-6	NiCr19Co14MoTiAlFe	0.03 to 0.10	≤ 0.75	≤ 1.00	≤ 0.030	≤ 0.030	18.00 to 21.00	3.50 to 5.00	Base	—	—	—	Ti = 2.75 to 3.25, Al = 1.20 to 1.60 Zr = 0.02 to 0.12, Cu = ≤ 0.50 B = 0.003 to 0.010 Fe = ≤ 2.00 Co = 12.00 to 15.00
xviii)	VSA-7	NiCr20Co17TiFe	0.13 *Max*	1.50 *Max*	1.00 *Max*	—	—	18.00 to 21.00	—	Base	—	—	—	Ti = 1.80 to 3.00, Co = 15.0 to 21.0, Fe = 3.00 *Max*

Table 1 (*Concluded*)

Sl No.	Designation		C	Si	Mn	P	S	Cr	Mo	Ni	V	Nb	Ti	Others
	Number	Grade												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
xix)	VSA-8	X5NiCrTiAl30-15-2	≤ 0.08	≤ 0.50	≤ 0.50	≤ 0.015	≤ 0.015	13.50 to 15.50	0.40 to 1.00	29.50 to 33.50	—	0.40 to 0.90	2.30 to 2.90	Al = 1.60 to 2.20, B = 0.010 *Max*
Titanium Alloys														
xx)	VTA-1	TiAl6V4	0.10 *Max*	—	—	—	—	—	—	—	3.35 to 4.65	—	Base	N = 0.10 *Max*, Al = 5.25 to 6.75 O = 0.40 *Max*, Fe = 0.80 *Max*, H = 0.020 *Max*, Y = 0.005 *Max*
xxi)	VTA-2	TiAl6Zr4Mo2Sn2	0.05 *Max*	—	—	—	—	—	1.80 to 2.20	—	—	—	Base	Si = 0.20 *Max*, N = 0.07 *Max*, Al = 5.50 to 6.50, Y = 0.005 *Max*, Zr = 3.60 to 4.40, H = 0.015 *Max*, Sn = 1.80/2.20, O = 0.20 *Max*, Fe = 0.25 *Max*

Table 2 Permissible Variation in Product Analysis

(*Clause* 7.2)

Sl No.	**Constituent**	**Specified Limits of Ladle Analysis,** Percent	**Variation over Specified Limit,** Percent**,** *Max*
(1)	(2)	(3)	(4)
i)	C	< 0.20	± 0.01
		≥ 0.20 to < 0.60	± 0.02
		≥ 0.60 to ≤ 0.90	± 0.03
ii)	Si	≤ 1.00	± 0.05
		> 1.00 to ≤ 3.30	± 0.10
iii)	Mn	< 1.00	± 0.03
		≥ 1.00 to ≤ 2.00	± 0.04
		> 2.00 to ≤ 10.00	± 0.06
iv)	P	≤ 0.040	+ 0.005
		> 0.040 to ≤ 0.045	+ 0.010
v)	S	≤ 0.030	+ 0.005
vi)	Cr	≥ 8.00 to ≤ 10.00	± 0.10
		> 10.00 to ≤ 15.00	± 0.15
		> 15.00 to ≤ 20.00	± 0.20
		> 20.00 to ≤ 24.00	±0.25
vii)	Mo	< 1.75	± 0.05
		≥ 1.75 to ≤ 2.50	± 0.10
viii)	Ni	< 5.00	± 0.07
		≥ 5.00 to ≤ 9.00	± 0.10
ix)	V	≥ 0.30 to ≤ 0.60	± 0.03
x)	Nb + Ta	≥ 1.80 to ≤ 3.00	± 0.05
xi)	W	≤ 1.50	± 0.05
xii)	N	≤ 0.60	± 0.02

NOTES

1 The permissible limits for super alloys beyond the range specified above shall be mutually agreed.

2 The permissible limit for elements not specified above shall be mutually agreed.

Table 3 Hardness and Tensile Strength for Material Supplied in Heat Treatment Condition

(*Clause* 9.1)

Sl No.	Designation		Heat Treatment Condition	Hardness	Tensile Strength MPa
	Number	Grade			
(1)	(2)	(3)	(4)	(5)	(6)
Martensitic Steels					
i)	VM-1	X45CrSi 9-3	AH	300 HB *Max*	**
			QH+T	266 HB to 325 HB	1 100 *Max*
ii)	VM-2	X40CrSiMo 10-2	AH	300 HB *Max*	**
iii)	VM-3	X50CrSi 8-2	AH	300 HB *Max*	**
			QH+T	266 HB to 325 HB	1 100 *Max*
iv)	VM-4	40CrMoV47	**	**	**
v)	VM-5	X85CrMoV 18-2	AH	300 HB *Max*	**
Austenitic Steels					
vi)	VA-1	X55CrMnNiN 20-8	SH (1 000 °C to 1 100 °C)	385 HB *Max*	1 300 *Max*
vii)	VA-2	X53CrMnNiN 21-9	SH (1 000 °C to 1 100 °C)	385 HB *Max*	1 300 *Max*
viii)	VA-3	X33CrNiMnN 23-8	SH (1 000 °C to 1 100 °C)	360 HB *Max*	1 250 *Max*
ix)	VA-4	X20CrNiMnN 21-12	**	**	**
x)	VA-5	X50CrMnNiNbN 21-9	SH (1 000 °C to 1 100 °C)	385 HB *Max*	1 300 *Max*
Super Alloys					
xi)	VSA-1	NiCr20TiAl	SH (930 °C to 1 030 °C)	325 HB *Max*	1 100 *Max*
xii)	VSA-2	NiCr15Fe7TiAl	SH (930 °C to 1 030 °C)	325 HB *Max*	1 100 *Max*
xiii)	VSA-3	NiCr22TiMoAl	**	**	
xiv)	VSA-4	NiCr22TiMoAlCo	**	**	
xv)	VSA-5	NiFe25Cr20NbTi	SH (930 °C to 1 030 °C)	295 HB *Max*	1 000 *Max*
xvi)	VSA-6	NiCr19Co14MoTiAlFe	**	**	**
xvii)	VSA-7	NiCr20Co17TiFe	**	**	**
xviii)	VSA-8	X5NiCrTiAl 30-15-2	**	**	**
Titanium Alloys					
xix)	VTA-1	TiAl6V4	**	**	**
xx)	VTA-2	TiAl6Zr4Mo2Sn2	**	**	**

NOTES

1 AH- Annealing Heat Treatment, QH- Quenching Heat Treatment, SH- Solution Heat Treatment, T- Tempering.

2 **Heat treatment condition, supply hardness and tensile strength shall be mutually agreed at the time of ordering.

Table 4 Reference Data for Hot Forming and Heat Treatment

(*Clause* 9.3.1)

Sl No.	Designation		Hot Forming	Annealing	Quenching/Solution Heat Treatment	Quench Media	Tempering/Ageing
	Number	Grade					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Martensitic Steels							
i)	VM-1	X45CrSi 9-3	1 100 °C to 900 °C	780 °C to 820 °C/air or water	1 000 °C to 1 050 °C	Oil	720 °C to 820 °C/air or water
ii)	VM-2	X40CrSiMo 10-2	1 100 °C to 900 °C	780 °C to 820 °C/air or water	1 000 °C to 1 050 °C	Oil	720 °C to 820 °C/air or water
iii)	VM-3	X50CrSi 8-2	1 100 °C to 900 °C	780 °C to 820 ° C/air or water	1 000 °C to 1 050 °C	Oil	720 °C to 820 °C/air or water
iv)	VM-4	40CrMoV47	1 230 °C to 925 °C	**	857 °C to 885 °C	Oil	663 °C to 691 °C/air
v)	VM-5	X85CrMoV 18-2	1 100 °C to 900 °C	820 °C to 869 °C /Retarded cooling	1 050 °C to 1 080 °C	Oil	720 °C to 820 °C/air
Austenitic Steels							
vi)	VA-1	X55CrMnNiN 20-8	1 100 °C to 950 °C	—	1 140 °C to 1 180 °C	Water	760 ° C to 815 ° C/4 h air – 8 h air
vii)	VA-2	X53CrMnNiN 21-9	1 100 °C to 950 °C	—	1 140 °C to 1 180 °C	Water	760 ° C to 815 ° C/4 h air – 8 h air
viii)	VA-3	X33CrNiMnN 23-8	1 150 °C to 980 °C	—	1 150 °C to 1 170 °C	Water	800 ° C to 830 °C/8 h air

Table 4 (*Concluded*)

Sl No.	Designation		Hot Forming	Annealing	Quenching/Solution Heat Treatment	Quench Media	Tempering/Ageing
	Number	Grade					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ix)	VA-4	X20CrNiMnN 21-12	1 150 °C to 950 °C	—	1 168 °C to 1 196 °C	Water	746 °C to 774 °C/4 h air – 10 h air
x)	VA-5	X50CrMnNiNbN 21-9	1 150 °C to 950 °C	—	1 160 °C to 1 200 °C	Water	760 °C to 815 °C/4 h air – 8 h air
Super Alloys							
xi)	VSA-1	NiCr20TiAl	1 150 °C to 1 050 °C	—	1 000 °C to 1 080 °C	Air/water	690 °C to 710 °C/16 h air
xii)	VSA-2	NiCr15Fe7TiAl	1 150 °C to 940 °C	—	1 100 °C to 1 150 °C	Air	840 °C/24 h + 700 °C/2 h air –16 h air
xiii)	VSA-3	NiCr22TiMoAl	1 150 °C to 1 050 °C	—	1 079 °C to 1 107 °C	Oil	677 °C to 732 °C/2 h air – 16 h air
xiv)	VSA-4	NiCr22TiMoAlCo	1 150 °C to 1 050 °C	—	1 079 °C to 1 107 °C	Oil	677 °C to 732 °C/2 h air – 16 h air
xv)	VSA-5	NiFe25Cr20NbTi	1 150 °C to 1 050 °C	—	1 000 °C to 1 080 °C	Air/water	690 °C to 710 °C/16 h air
xvi)	VSA-6	NiCr19Co14MoTiAlFe	**	—	**	**	**
xvii)	VSA-7	NiCr20Co17TiFe	**	—	**	**	**
xviii)	VSA-8	X5NiCrTiAl 30-15-2	**	—	**	**	**
Titanium Alloys							
xix)	VTA-1	TiAl6V4	**	—	**	**	**
xx)	VTA-2	TiAl6Zr4Mo2Sn2	**	—	**	**	**

NOTE — ** Heat treatment condition and supply hardness shall be mutually agreed at the time of ordering.

Table 5 Reference Values for Mechanical Properties at Room Temperature

(*Clause* 9.3 *and* 9.3.1)

Sl No.	Designation		Heat Treatment	Hardness	0.2 % Proof Stress MPa	Tensile Strength MPa	Elongation, percent	Reduction in Area, percent
	Number	Grade						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Martensitic Steels								
i)	VM-1	X45CrSi 9-3	QH + T	266 HB to325 HB	700	900 to 1 100	14	40
ii)	VM-2	X40CrSiMo 10-2	QH + T	266 HB to 325 HB	700	900 to 1 100	14	40
iii)	VM-3	X50CrSi 8-2	QH + T	266 HB to 325 HB	685	900 to 1 100	14	40
iv)	VM-4	40CrMoV47	QH + T	35 HRC	1000	1 100	18	60
v)	VM-5	X85CrMoV 18-2	QH + T	296 HB to 355 HB	800	1 000 to 1 200	7	12
Austenitic Steels								
vi)	VA-1	X55CrMnNiN 20-8	SH + A	28 HRC	550	900 to 1 150	8	10
vii)	VA-2	X53CrMnNiN 21-9	SH + A	30 HRC	580	950 to 1 200	8	10
viii)	VA-3	X33CrNiMnN 23-8	SH + A	25 HRC	550	850 to 1 100	20	30
ix)	VA-4	X20CrNiMnN 21-12	SH + A	23 HRC to 25 HRC	415 to 763	795 to 865	35 to 45	45 to 55
x)	VA-5	X50CrMnNiNbN 21-9	SH + A	30 HRC	580	950 to 1 150	12	15

Table 5 (*Concluded*)

Sl No.	Designation		Heat Treatment	Hardness	0.2 % Proof Stress MPa	Tensile Strength MPa	Elongation, percent	Reduction in Area, percent
	Number	Grade						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Super Alloys								
xi)	VSA-1	NiCr20TiAl	SH + A	32 HRC	725	1 100 to 1 400	15	25
xii)	VSA-2	NiCr15Fe7TiAl	SH + A	32 HRC	750	1 100 to 1 300	12	20
xiii)	VSA-3	NiCr22TiMoAl	SH + A	32 HRC to 37 HRC	692 to 830	1 103 to1 300	25 to 35	5 to 45
xiv)	VSA-4	NiCr22TiMoAlCo	SH + A	32 HRC to 37 HRC	692 to 830	1 103 to 1 300	25 to 35	5 to 45
xv)	VSA-5	NiFe25Cr20NbTi	SH + A	28 HRC	500	900 to 1 100	25	30
xvi)	VSA-6	NiCr19Co14MoTiAlFe	SH + A	32 HRC to 45 HRC	1030	1 280	**	15
xvii)	VSA-7	NiCr20Co17TiFe	SH + A	32 HRC to 42 HRC	690 to 750	1 014 to 1 175	30 to 36	35
xviii)	VSA-8	X5NiCrTiAl 30-15-2	SH + A	31 HRC to 39 HRC	655 to 670	1 124 to 1 128	34 to 35	54 to 55
Titanium Alloys								
xix)	VTA-1	TiAl6V4	SH + A	**	**	**	**	**
xx)	VTA-2	TiAl6Zr4Mo2Sn2	SH + A	**	**	**	**	**

NOTES

1 A= Ageing, PS = Proof Stress, TS = Tensile Strength.

2 **Heat treatment condition and mechanical properties shall be mutually agreed at the time of ordering if required.

Table 6 Reference Values for Tensile Properties at Elevated Temperatures

(*Clause* 9.3 *and* 9.3.1)

Sl No.	Grade		Heat Treatment	Tensile Properties at 500 °C		Tensile Properties at 550 °C		Tensile Properties at 600 °C		Tensile Properties at 650 °C		Tensile Properties at 700 °C		Tensile Properties at 750 °C		Tensile Properties at 800 °C	
	Number	Name		0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Martensitic Steels																	
i)	VM-1	X45CrSi 9-3	QH + T	400	500	300	360	240	250	120	170	80	110	**	**	NA	NA
ii)	VM-2	X40CrSiMo 10-2	QH + T	450	550	350	420	260	300	180	220	100	130	**	**	NA	NA
iii)	VM-3	X50CrSi 8-2	QH + T	400	500	300	360	220	230	110	160	75	105	**	**	NA	NA
iv)	VM-4	40CrMoV47	QH + T	**	**	**	**	430	**	330	**	NA	NA	NA	NA	NA	NA
v)	VM-5	X85CrMoV 18-2	QH + T	500	550	370	400	280	300	170	230	120	180	80	140	NA	NA
Austenitic Steels																	
vi)	VA-1	X55CrMnNiN 20-8	SH + A	300	640	280	590	250	540	230	490	220	440	200	360	170	290
vii)	VA-2	X53CrMnNiN 21-9	SH + A	350	650	330	600	300	550	270	500	250	450	230	370	200	300
viii)	VA-3	X33CrNiMnN 23-8	SH + A	270	600	250	570	220	530	210	470	190	400	180	340	170	280
ix)	VA-4	X20CrNiMnN 21-12	SH + A	**	**	**	**	**	**	**	420	**	**	**	**	**	**
x)	VA-5	X50CrMnNiNb N 21-9	SH + A	350	680	330	650	310	610	285	550	260	480	240	410	220	340

Table 6 (*Concluded*)

Sl No.	Grade		Heat Treatment	Tensile Properties at 500 °C		Tensile Properties at 550 °C		Tensile Properties at 600 °C		Tensile Properties at 650 °C		Tensile Properties at 700 °C		Tensile Properties at 750 °C		Tensile Properties at 800 °C	
	Number	Name		0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa	0.2 % Proof stress MPa	Tensile strength MPa
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Super Alloys																	
xi)	VSA-1	NiCr20TiAl	SH + A	700	1 050	650	1 030	600	1 000	600	930	600	820	500	680	450	500
xii)	VSA-2	NiCr15Fe7TiAl	SH + A	725	1 000	710	980	690	930	660	850	650	770	560	650	425	510
xiii)	VSA-3	NiCr22TiMoAl	SH + A	**	**	**	**	**	**	648 to 750	1 055 to 1 150	**	**	**	**	**	**
xiv)	VSA-4	NiCr22TiMoAlCo	SH + A	**	**	**	**	**	**	648 to 750	1 055 to 1 150	**	**	**	**	**	**
xv)	VSA-5	NiFe25Cr20NbTi	SH + A	450	800	450	800	450	790	450	740						
xvi)	VSA-6	NiCr19Co14MoTiAlFe	SH + A	**	**	**	**	**	**	**	**	**	**	**	**	**	**
xvii)	VSA-7	NiCr20Co17TiFe	SH + A	**	**	**	**	**	**	**	**	**	**	**	**	**	**
xviii)	VSA-8	X5NiCrTiAl30-15-2	SH + A	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Titanium Alloys																	
xix)	VTA-1	TiAl6V4	SH + A	**	**	**	**	**	**	**	**	**	**	**	**	**	**
xx)	VTA-2	TiAl6Zr4Mo2Sn2	SH + A	**	**	**	**	**	**	**	**	**	**	**	**	**	**

NOTE — **Tensile strength and 0.2 percent proof stress values shall be mutually agreed at the time of ordering if required.

Table 7 Reference Values for Creep Strength after 1 000 h

(*Clause* 9.3 *and* 9.3.1)

Sl No.	Designation		Creep strength after 1 000 h, Mpa			
	Number	**Grade**	**500 ºC**	**650 ºC**	**725 ºC**	**800 ºC**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Martensitic Steels						
i)	VM-1	X45CrSi 9-3	190	40	**	**
ii)	VM-2	X40CrSiMo 10-2	210	40	**	**
iii)	VM-3	X50CrSi 8-2	190	**	**	**
iv)	VM-4	40CrMoV47	**	**	**	**
v)	VM-5	X85CrMoV 18-2	260	52	18	-
Austenitic Steels						
vi)	VA-1	X55CrMnNiN 20-8	**	160	85	45
vii)	VA-2	X53CrMnNiN 21-9	**	200	110	50
viii)	VA-3	X33CrNiMnN 23-8	**	200	110	50
ix)	VA-4	X20CrNiMnN 21-12	**	**	**	**
x)	VA-5	X50CrMnNiNbN 21-9	**	220	120	55
Super Alloys						
xi)	VSA-1	NiCr20TiAl	**	500	290	150
xii)	VSA-2	NiCr15Fe7TiAl	**	475	260	125
xiii)	VSA-3	NiCr22TiMoAl	**	**	**	**
xiv)	VSA-4	NiCr22TiMoAlCo	**	**	**	**
xv)	VSA-5	NiFe25Cr20NbTi	**	400	180	60
xvi)	VSA-6	NiCr19Co14MoTiAlFe	**	**	**	**
xvii)	VSA-7	NiCr20Co17TiFe	**	**	**	**
xviii)	VSA-8	X5NiCrTiAl 30-15-2	**	**	**	**
Titanium Alloys						
xix)	VTA-1	TiAl6V4	**	**	**	**
xx)	VTA-2	TiAl6Zr4Mo2Sn2	**	**	**	**

NOTES — ** Creep strength values shall be mutually agreed at the time of ordering if required.

Table 8 Reference Data Relating to Physical Properties

(*Clause* 12)

Sl No.	Designation		Density at 20 °C	Modulus of Elasticity at 20 °C	Thermal Expansion Coefficient between 20 °C and				Thermal Conductivity 20 °C	Specific Heat Capacity at 20 °C	Magnetizability
	Number	Grade			100 °C	300 °C	500 °C	700 °C			
			Kg/dm^3	kN/mm^2	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	W/(mK)	J/kgK	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Martensitic Steels											
i)	VM-1	X45CrSi 9-3	7.7	210	10.9	11.2	11.5	11.8	21	500	Existent
ii)	VM-2	X40CrSiMo 10-2	7.7	210	10.9	11.2	11.5	11.8	21	500	Existent
iii)	VM-3	X50CrSi 8-2	7.7	210	10.9	11.2	11.5	11.8	21	500	Existent
iv)	VM-4	40CrMoV47	7.81	210	—	—	—	—	—	—	Existent
v)	VM-5	X85CrMoV 18-2	7.7	210	10.9	11.2	11.5	11.8	21	500	Existent
Austenitic Steels											
vi)	VA-1	X55CrMnNiN 20-8	7.8	205	15.5	17.5	18.5	18.8	14.5	500	Non-existent[#]
vii)	VA-2	X53CrMnNiN 21-9	7.8	205	15.5	17.5	18.5	18.8	14.5	500	Non-existent[#]
viii)	VA-3	X33CrNiMnN 23-8	7.8	205	16.5	17.1	17.3	17.4	14.5	500	Non-existent[#]
ix)	VA-4	X20CrNiMnN 21-12	7.7 to 7.8	201	—	—	—	—	—	—	—
x)	VA-5	X50CrMnNiNbN 21-9	7.8	205	15.5	17.5	18.5	18.8	14.5	500	Non-existent[#]

Table 8 (*Concluded*)

Sl No.	Designation		Density at 20 °C	Modulus of Elasticity at 20 °C	Thermal Expansion Coefficient between 20 °C and				Thermal Conductivity 20 °C	Specific Heat Capacity at 20 °C	Magnetizability
	Number	Grade			100 °C	300 °C	500 °C	700 °C			
			Kg/dm^3	kN/mm^2	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	$10^{-6}.K^{-1}$	W/(mK)	J/kgK	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Super Alloys											
xi)	VSA-1	NiCr20TiAl	8.3	215	11.9	13.1	13.7	14.5	13	460	Non-existent
xii)	VSA-2	NiCr15Fe7TiAl	8.3	215	13	14	14.5	15.5	13	460	Non-existent
xiii)	VSA-3	NiCr22TiMoAl	7.9 to 8.0	208	14.1	—	—	—	13	460	—
xiv)	VSA-4	NiCr22TiMoAlCo	7.9 to 8.0	208	14.1	—	—	—	13	460	—
xv)	VSA-5	NiFe25Cr20NbTi	8.1	215	14.1	15.5	15.9	16.8	13	460	Non-existent
xvi)	VSA-6	NiCr19Co14MoTiAlFe	—	—	—	—	—	—	—	—	—
xvii)	VSA-7	NiCr20Co17TiFe	—	—	—	—	—	—	—	—	—
xviii)	VSA-8	X5NiCrTiAl 30-15-2	7.9	201	—	—	—	—	13	—	—
Titanium Alloys											
xix)	VTA-1	TiAl6V4	—	—	—	—	—	—	—	—	—
xx)	VTA-2	TiAl6Zr4Mo2Sn2	—	—	—	—	—	—	—	—	—

Austenitic steel may be slightly magnetisable in aged condition. Their magnetizability may increase with extended cold forming.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 228 (all parts)	Methods of chemical analysis of steels
IS 919	Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes:
(Part 1) : 2014/ ISO 286-1 : 2010	Basis of tolerance, deviation and fits (*third revision*)
(Part 2) : 2014/ ISO 286-2 : 2010	Tables of standard tolerance classes and limit deviation for holes shafts (*second revision*)
IS 1500 (Part 1) : 2019/ ISO 6506-1 : 2014	Metallic materials — Brinell hardness test: Part 1 Test method (*fifth revision*)
IS 1586 (Part 1) : 2018/ ISO 6508-1 : 2016	Metallic materials — Rockwell hardness test: Part 1 Test method (*fifth revision*)
IS 1608	Metallic materials — Tensile testing:
(Part 1) : 2022/ ISO 6892-1 : 2019	Method of test at room temperature (*fifth revision*)
(Part 2) : 2020/ ISO 6892-2 : 2018	Method of test at elevated temperature (*fourth revision*)
IS 1956 (all parts)	Glossary of terms related to iron and steel
IS 3407	Method for creep testing of steel at elevated temperatures:
(Part 1) : 1983	Tensile creep testing (*first revision*)
(Part 2) : 1983	Tensile creep stress rupture testing (*first revision*)
IS 3711 : 2020/ ISO 377 : 2017	Steel and steel products — Location and preparation of samples and test pieces for mechanical testing (*third revision*)
IS 3739 : 1987	Dimensional tolerances for carbon and alloy constructional steel products (*first revision*)
IS 4163 : 2021/ ISO 4967 : 2013	Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams (*fourth revision*)
IS 4748 : 2021/ ISO 643 : 2019	Steels — Micrographic determination of the apparent grain size (*third revision*)
IS 8910 : 2022/ ISO 404:2013	General technical delivery requirements for steel and steel products (*second revision*)
IS 10604 (Part 2) : 1983	Machining allowances and tolerances for open die steel forging: Part 2 High alloy steel forgings
IS/ISO 14284 : 1996	Steel and iron — Sampling and preparation of samples for the determination of chemical composition
IS/ISO 16124 : 2015	Steel wire rod — Dimensions and tolerances (*first revision*)
IS 17795 : 2022/ ISO 204 : 2018	Metallic materials — Uniaxial creep testing in tension — Method of test

ANNEX B

(*Clause* 5.2)

Sl No.	Designation in IS		Equivalent International Grades			
	Number	Grade	ISO	DIN	SAE	JIS
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	VM-1	X45CrSi 9-3	X45CrSi 9 3	X45CrSi9-3	—	SUH 1
ii)	VM-2	X40CrSiMo 10-2	—	X40CrSiMo10-2	—	SUH 3
iii)	VM-3	X50CrSi 8-2	X50CrSi 8 2	—	—	SUH 11
iv)	VM-4	40CrMoV47	—	—	K14072	SNB 16
v)	VM-5	X85CrMoV 18-2	X85CrMoV 18 2	X85CrMoV18-2	—	—
vi)	VA-1	X55CrMnNiN 20-8	X55CrMnNiN20 8	X55CrMnNiN20-8	—	—
vii)	VA-2	X53CrMnNiN 21-9	X53CrMnNi219	X53CrMnNi21-9	—	SUH 35
viii)	VA-3	X33CrNiMnN 23-8	X33CrNiMn23 8	X33CrNiMn23-8	—	—
ix)	VA-4	X20CrNiMnN 21-12	—	—	21 to12	SUH 37
x)	VA-5	X50CrMnNiNbN 21-9	X50CrMnNiNb21-9	X50CrMnNiNb21-9	—	—
xi)	VSA-1	NiCr20TiAl	NiCr20TiAl	NiCr20TiAl	—	NCF 80A
xii)	VSA-2	NiCr15Fe7TiAl	NiCr15Fe7TiAl	NiCr15Fe7TiAl	—	NCF 751
xiii)	VSA-3	NiCr22TiMoAl	—	—	N07031	—
xiv)	VSA-4	NiCr22TiMoAlCo	—	—	N07032	—
xv)	VSA-5	NiFe25Cr20NbTi	NiFe25Cr20NbTi	NiFe25Cr20NbTi	—	—
xvi)	VSA-6	NiCr19Co14MoTiAlFe	—	—	Waspaloy	—
xvii)	VSA-7	NiCr20Co17TiFe	—	—	Nimonic 90	—
xviii)	VSA-8	X5NiCrTiAl 30-15-2	—	—	Ni 30	—
xix)	VTA-1	TiAl6V4	—	—	R56401	—
xx)	VTA-2	TiAl6Zr4Mo2Sn2	—	—	R54620	—

ANNEX C

(*Foreword*)

COMMITTEE COMPOSITION

Alloy Steels and Forgings Sectional Committee, MTD 16

Organization	*Representative(s)*
Mishra Dhatu Nigam Limited, Hyderabad	SHRI T. MUTHUKUMAR **(*Chairperson*)**
All Indian Stainless Steel Industries Association, Mumbai	SHRI HITENDERA BHALARIA SHRI JAY KUMAR BANSAL (*Alternate*)
Atomic Mineral Division, Nagpur/New Delhi	DR SMEER DURANI SHRI ALOK PANDEY (*Alternate*)
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Directorate General Quality Assurance, New Delhi	SHRI L. P. VARTE SHRI M. K. SHRIVASTAV (*Alternate*)
Hindustan Aeronautical Limited (HAL), Bangalore	DR R.R. BHAT SHRI ANIL KUMAR M. (*Alternate*)
Indian Stainless Steel Development Association, Gurugram	SHRI ROHIT KUMAR
Indira Gandhi Centre for Atomic Research, Kalpakkam	SHRI UTPAL BOHRA
Jindal Stainless Limited, Hissar	SHRI BISWABASU ROY CHOWDHURY SHRI V NARASIMHA RAO (*Alternate*)
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Ministry of commerce and Industry, DPIIT, New Delhi	SHRI S.K.JAIN
Ministry of Steel, New Delhi	SHRI PARMJEET SINGH SHRI B. PRADHAN (*Alternate*)
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Mukand Ltd, Kalwe	SHRI M. M. RAO SHRI SUNIL NAIR (*Alternate*)

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Steel Authority of India Limited (SAIL) - Salem Steel Plant, Salem	SHRI P. GOVINDRAJAN SHRI VIRENDER VEER (*Alternate*)
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Panel for formulation of standard on alloy steels for valves for automobiles MTD 16/P 8

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Star Wire (India) Limited, Faridabad	DR S. S. KASANA **(*Convenor*)** DR AVNISH KUMAR
Hitachi Metals (India) Private Limited, Gurugram	SHRI K. THUKARAM
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Society of Indian Automobile Manufacturers (SIAM), New Delhi	SHRI KARTIKE KARWAL
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Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	265 9930
Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
Western	: Plot No. E-9, Road No.-8, MIDC, Andheri (East), Mumbai 400093	2821 8093

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